LITHIUM

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Introduction

Chile has been the world's leading producer of lithium carbonate since 1997, the first year that it surpassed U.S. production. Production in Chile was from two lithium brine operations on the Salar de Atacama in the Andes Mountains and two lithium carbonate plants in Antofagasta. In the United States, production continued at a single lithium brine operation with an associated lithium carbonate plant in Nevada. Lithium carbonate and lithium chloride also were produced from brines from the Salar del Hombre Muerto in the Argentine Andes. China was the only country producing lithium carbonate from lithium minerals. Australia, Canada, and Zimbabwe were important sources of lithium concentrates. A large percentage of the lithium carbonate produced in South America was exported to the United States for consumption in industrial applications and as feed material for the production of downstream lithium compounds, such as lithium hydroxide monohydrate, lithium metal, and organic lithium compounds.

Lithium is sold as brines, compounds, metal, or mineral concentrates depending on the end use. Lithium's electrochemical reactivity and other unique properties have resulted in many commercial lithium products. Most lithium compounds and minerals are consumed in the production of ceramics, glass, and primary aluminum. The consumption of various lithium compounds in lithium batteries, the use of organic lithium compounds as industrial catalysts, and lithium compound additions to concrete are rapidly expanding markets.

Production

The U.S. Geological Survey (USGS) collects domestic production data for lithium from a voluntary canvass of U.S. operations. The single U.S. lithium carbonate producer, Chemetall Foote Corp. (a subsidiary of the German company Chemetall GmbH), responded to the survey, representing 100% of total production. Production and stock data were withheld from publication to avoid disclosing company proprietary data (table 1).

Chemetall Foote produced lithium carbonate from brines near Silver Peak, NV. The company's other U.S. lithium operations included a lithium hydroxide plant in Silver Peak; a butyllithium plant in New Johnsonville, TN; and facilities for producing downstream lithium compounds in Kings Mountain, NC. Chemetall Foote's subsidiary in Chile, Sociedad Chilena de Litio Ltda. (SCL) produces lithium carbonate and lithium hydroxide from a brine deposit.

FMC Corp.'s Lithium Division produced a full range of downstream compounds, lithium metal, and organic lithium compounds at its facilities in Bessemer City, NC, and Bayport, TX. FMC met most of its lithium carbonate requirements through a long-term agreement with Chilean producer Sociedad Quimica y Minera de Chile S.A. (SQM) to supply it with lithium carbonate produced at SQM's brine operation. FMC produced lithium carbonate and lithium chloride in Argentina in 2003.

LithChem International (a subsidiary of ToxCo, Inc.) of Anaheim, CA, produced lithium carbonate and lithium hydroxide at its plant in Baltimore, OH. LithChem produces these compounds from lithium compounds that are products of ToxCo's lithium battery recycling operation in Trail, British Columbia, Canada. Another ToxCo subsidiary (Ozark Fluorine Specialties Inc., in Tulsa, OK) produces hydrofluoric acid, some of which is converted to lithium hexafluorophosphate, high-purity lithium fluoride, and other electrolytes used in lithium batteries (McCoy, 2002).

Lithium carbonate is the most important lithium compound produced from brines and ore deposits. In most cases, other lithium compounds require lithium carbonate as a feedstock for further processing. The only domestic producer of lithium carbonate from brine is Chemetall Foote's operation in Nevada. Nevada brines enriched in lithium chloride, which averaged about 300 parts per million (ppm) when Foote Mineral Co. (the original owner of the deposit) began operations in 1966, are pumped from the ground and move through a series of evaporation ponds (Engineering and Mining Journal, 1970). During the course of 12 to 18 months, the concentration of the brine increases through solar evaporation to 6,000 ppm lithium. When the lithium chloride reaches optimum concentration, the liquid is pumped to a recovery plant and treated with soda ash, precipitating lithium carbonate. The carbonate is then removed through filtration, dried, and shipped. A similar process is used to recover lithium from the Chilean brines, with slight adjustments to account for their chemical differences. The brine operation in Argentina uses a different, proprietary technology that allows for the lithium recovery as either carbonate or chloride.

Until the last domestic mine closed in 1998, spodumene had been the major raw material used for the production of lithium carbonate in North Carolina, and small amounts of spodumene concentrate also were produced for sale. Spodumene is the most common lithium mineral, but the minerals petalite and lepidolite are mined in different parts of the world for their lithium content. These three minerals are beneficiated to produce lithium concentrates that can be used directly in certain applications.

Producing lithium carbonate from spodumene entails an energy-intensive chemical recovery process, which is more costly than that used to recover lithium carbonate from brines. Because of the high cost of producing lithium carbonate from spodumene, the majority of world lithium carbonate production has shifted to brine deposits. Spodumene was believed to be the source of most lithium carbonate production in China. After mining, spodumene is crushed and undergoes a flotation beneficiation process to produce concentrate. The concentrate is heated to between 1,075° C and 1,100° C, changing the crystal structure of the mineral and making it more reactive with sulfuric acid. A mixture of finely ground converted spodumene and sulfuric acid is heated to 250° C, forming lithium sulfate. Water is added to the mixture to dissolve the lithium sulfate. Insoluble portions are then removed by filtration. The purified lithium sulfate solution is treated with soda ash, forming insoluble lithium carbonate that precipitates from solution. The carbonate is separated and dried for sale or use by the producer as feedstock in the production of other lithium compounds.

Consumption

The aluminum, ceramics and glass, lubricating grease, and synthetic rubber industries used most of the lithium minerals and compounds consumed in 2003. Estimated domestic consumption had been stable from 1997 through 2000, but in 2001, consumption plummeted to only 50% of what it was in the 4 previous years. In 2002, consumption decreased an additional 21%, resulting in consumption of less than 40% of what it had been only 2 years earlier. In 2001, primary aluminum production, a major end use for lithium carbonate, decreased 28% from the previous year. Primary aluminum production has remained low since that time. Consumption estimates indicated a further decrease in lithium consumption in other end uses, including ceramics and glass, lubricants, synthetic rubber, and pharmaceuticals, although data to support this assumption were not available. Estimated consumption of lithium in 2003 rebounded slightly, but only to the level achieved in 2001. This rebound can be attributed to the recovery of consumption in all end uses except aluminum as a result of an improving economy.

When lithium concentrates were included in lithium consumption estimates, the largest use of lithium in the United States was in ceramics and glass manufacturing processes. The addition of lithium as lithium carbonate or lithium concentrates to the glass melt lowers process melting point, reduces the coefficient of thermal expansion and the viscosity, and eliminates the use of more toxic compounds. The production of ceramics and glass was the only commercial use for lithium mineral concentrates. The domestic manufacture of thermal shock-resistant cookware (pyroceramics) consumed the majority of lithium used in the ceramics and glass industry. The closure of a large cookware factory in West Virginia during 2002 dramatically decreased the consumption of lithium mineral concentrates for this application. An increasing use for lithium in ceramics and glass is in glass cooktops; much of this material is produced in Europe (Crossley, 2003b). Low-iron spodumene and petalite were sources of the lithium used to improve the physical properties of container and bottle glass as well as sources of alumina, another important component of glass. Glass manufacturers used lithium in container and bottle glass to produce a lighter weight, thinner walled product. Lithium concentrates are the predominant lithium source for ceramics and glass uses, but lithium carbonate also is used.

Primary aluminum production is the second largest use of lithium, although at lower levels than before closure of several aluminum smelters in 2001. Adding lithium carbonate to aluminum potlines lowers the melting point of the cryolite bath, allows a lower operating temperature for the cells, increases the electrical conductivity, and decreases bath viscosity. These factors contribute to increased production without changing any other operating conditions. Lithium carbonate additions have the environmental benefit of reducing fluorine emissions by 20% to 30%. Many U.S. smelters are older than those in other countries, so they require more lithium carbonate than more modern aluminum smelters that are more efficient and less polluting by design (Chemetall GmbH, undated§[1]).

Domestically, another large end use for lithium compounds was as catalysts in the production of synthetic rubbers, plastics, and pharmaceuticals. N-butyllithium is used to initiate the reactions between styrene and butadiene that form abrasion-resistant synthetic rubbers that require no vulcanization. Other organic lithium compounds were used as catalysts for the production of plastics, such as polyethylene. Lithium metal and organic compounds also were used as catalysts in the production of an analgesic, anticholesterol agents, antihistamines, contraceptives, sleep inducers, steroids, tranquilizers, vitamin A, and other products. Lithium catalysts were used in the production of protease inhibitors, important drugs in the treatment of human immunodeficiency virus type 1/acquired immunodeficiency syndrome (HIV/AIDS) (Schmitt, 2001). Pharmaceutical-grade lithium carbonate was used in the treatment of manic-depressive psychosis. This was the only treatment approved by the U.S. Food and Drug Administration in which lithium was consumed by the patient.

The multipurpose grease industry was another important market for lithium in 2003. Lithium hydroxide monohydrate was the compound used for the production of lithium lubricants. Lithium-based greases were favored for their retention of lubricating properties over a wide temperature range; good resistance to water, oxidation, and hardening; and formation of a stable grease on cooling after melting. These greases are used in aircraft, automotive, industrial, marine, and military applications.

Many major battery manufacturers marketed some type of lithium battery. Two major advantages of lithium batteries are their even discharge over time and their low tendency to self-discharge that gives them long shelf lives. Research and development continued, and innovative rechargeable battery configurations continued to be developed to meet the changing requirements of electronic equipment, such as portable telephones, portable computers, and video cameras. Worldwide, rechargeable lithium batteries power more than 60% of cellular telephones and 90% of the laptop computers (FMC Corp., 2004§). Lithium-ion batteries were of particular interest for these applications because they take advantage of the large power capacity available from lithium batteries with fewer safety problems than are encountered when batteries contain lithium metal, a very reactive and volatile material when exposed to air and moisture. Electric vehicles (EVs) have been considered a large potential market for lithium batteries, but general acceptance of these vehicles has been slow. Hybrid vehicles and vehicles powered by fuel cells may find greater popularity in the near future than pure EVs.

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[1]References that include a section mark (§) are found in the Internet References Cited section.

Nonrechargeable (primary) lithium batteries offer improved performance compared with alkaline batteries at a slightly higher cost and have been commercially available for more than 10 years. They are used in cameras, electronic games, microcomputers, small appliances, toys, and watches. The military purchase lithium batteries for a variety of military applications.

Aircraft manufacturers in several countries have considered using aluminum-lithium alloys for wing and fuselage skin or for structural members in different types of aircraft. Use of these alloys could reduce the weight of the aircraft by more than 10%, allowing significant fuel savings during the life of the aircraft. The alloys, which are 2% to 3% lithium by weight, were attractive to the aircraft and aerospace industries because of their reduced density and improved corrosion resistance compared with conventional aluminum alloys. These alloys, however, have not been as widely used in aircraft manufacture as a result of direct competition from composite materials consisting of aramid, boron, or graphite fibers embedded in polymers.

The superlightweight external fuel tank for the National Aeronautics and Space Administration's space shuttle was made with another aluminum alloy containing 4% copper, 1% lithium, 0.4% magnesium, 0.4% silver, and the remainder aluminum. This alloy was 30% stronger and 5% less dense than the more traditional aluminum alloy that it replaced. The redesigned fuel tank weighed about 3,400 kilograms less than the original design; the weight savings were used to increase the payload capacity for shuttle missions (Light Metal Age, 1998).

Lithium was being used increasingly as a concrete additive for two reasons. Small additions of lithium can prevent or mitigate premature deterioration of concrete through alkali silica reactivity (ASR). In ASR, silica in the aggregate reacts with the alkali in the cement binder producing a silica gel that then absorbs water and expands sufficiently to create cracks in the concrete (FMC Corp., 2004§). Lithium compounds also are added to fast-setting cements, floor screeds, joint sealing mortars, and cement based adhesives to accelerate setting and hardening rates (Chemetall GmbH, undated§).

Small quantities of other lithium compounds were important to many industries. For example, lithium chloride and lithium bromide were used in industrial air-conditioning and commercial dehumidification systems and in the production of sophisticated textiles. Sanitizers for commercial glassware, public restrooms, and swimming pools contained lithium hypochlorite, as did dry bleaches for commercial laundries. Lithium metal was used as a scavenger to remove impurities from bronze and copper, and anhydrous lithium chloride was used as a component in fluxes for hard-to-weld metals, such as aluminum and steel alloys.

Prices

Lithium pricing has become very competitive since SQM entered the market in 1998. It has become difficult to obtain reliable price information from the companies or trade publications. The companies may announce price hikes, but they are reported relative only to previous prices. Producers negotiate with consumers on an individual basis; price information is not usually reported.

Customs values for lithium carbonate entering the United States from Chile are a good indication of the trends in lithium pricing, although they have never reflected exactly the producers' average prices for lithium carbonate. In 2003, the customs unit value for imported lithium carbonate was $1.55 per kilogram, slightly lower than in 2002.

Foreign Trade

In 2003, total exports of lithium compounds from the United States decreased by 5% compared with that of 2002. About 39% of all U.S. exports of lithium compounds was to Germany and Japan. The remainder was divided among many other countries (table 2).

Imports of lithium compounds increased by 14% in 2003 following 2 years of decreases. In 2003, 72% of lithium chemical imports came from Chile, 27% came from Argentina, and 1% from other countries (table 3). Lithium concentrates from Australia, Canada, and Zimbabwe were believed to have been consumed in the United States, but no import data were available.

World Review

A small number of countries throughout the world produced lithium concentrates and brine. Chile, China, and the United States were the leading producers of lithium carbonate. Significant quantities of lithium compounds and concentrates also were produced in Argentina, Australia, Brazil, Canada, Portugal, Russia, and Zimbabwe. Congo (Kinshasa), Namibia, Rwanda, and South Africa are past producers of concentrates. Production figures for lithium mineral concentrates, lithium carbonate, and lithium chloride are listed in table 4. Pegmatites containing lithium minerals have been identified in Austria, France, India, Ireland, Mozambique, Spain, and Sweden, but economic conditions have not favored development of the deposits. Lithium has been identified in subsurface brines in Bolivia, China, and Israel. Companies in France, Germany, Japan, Taiwan, and the United Kingdom produced downstream lithium compounds from imported lithium carbonate.

The total lithium market was estimated to be about 13,200 metric tons (t) of lithium contained in minerals and compounds in 2002, the last year for which this type of information was available. About 10,200 t of lithium was consumed as compounds, the remainder as concentrates. Global consumption of lithium minerals was estimated to be around 195,000 t in 2002, containing approximately 5,000 t of lithium (Crossley, 2003b).

Argentina.—Lithium carbonate production of 1,000 t and lithium chloride production of 4,700 t were estimated for 2003. FMC's Argentine facility was designed to produce about 12,000 metric tons per year (t/yr) of lithium carbonate and about 5,500 t/yr of lithium chloride, but production has never reached those levels (North American Mineral News, 1998).

Australia.—Sons of Gwalia Ltd. is the leading lithium mineral producer with 60% of world lithium concentrate capacity. It produces spodumene concentrates at the Greenbushes Mine in Western Australia. The company markets products ranging from 2.2% to 3.5% lithium (Crossley, 2003b).

Brazil.—Companhia Brasileira de Litio produces spodumene concentrates from the underground Cachoeira Mine in Araçuaí. This material is used as feedstock for lithium carbonate and lithium hydroxide production at a plant in Aguas Vermelhas in Minas Gerais. In Brazil, lithium compounds and minerals are used in greases and lubricants, primary aluminum production, ceramics, batteries, and nuclear reactors (Ramos, 2003).

Canada.—Tantalum Mining Corp. of Canada Ltd. (Tanco) (a subsidiary of Cabot Corp.) operates an underground spodumene mine and a concentrating plant at Bernic Lake, Manitoba. Tanco produces several grades of spodumene concentrates and two lithium phosphate concentrates. Six other lithium projects were under consideration, four of which were in the Separation Rapids region of Manitoba and Ontario.

The first project proposed was Avalon Ventures Ltd.'s Big Whopper petalite portion of its Separation Rapids rare metals project in northwestern Ontario; it was followed by Emerald Fields Resource Corp.'s Big Mack petalite project, on the same pegmatite body between the Tanco and Avalon operations. Neither deposit has been developed for commercial production because new product sources were not in high demand. Avalon proposed an operation to produce a high-lithium, low-iron feldspar product from Big Whopper instead of petalite concentrates as originally planned. Emerald Fields enlisted the help of a longtime petalite producer from Zimbabwe, Bikita Minerals Ltd., in evaluating the deposit and designing the concentration circuit based on Bikita's proven technology.

Champion Resources Ltd. and Gossan Resources Ltd. were exploring the lithium potential of their holdings in the Separation Rapids region. Tanco owned 50.1% of the Gossan Resources project, but was selling its portion of the project to Angus and Ross PLC of Boston, MA. Raymor Industries Inc. wanted to develop its La Motte property in Quebec to produce low-cost lithium metal directly from spodumene. Houston Lake Mining Inc. intended to evaluate a zoned spodumene-containing pegmatite deposit at Pakegama Lake in Ontario (Crossley, 2003a).

Chile.—With two large brine operations at the Salar de Atacama and their associated lithium carbonate plants, Chile was the largest lithium carbonate producer in the world. Chemetall Foote's plant first produced lithium carbonate in 1984, and current capacity is about 14,500 t/yr. It uses this lithium carbonate as feedstock for some of its downstream chemical production in the United States and supplies the operations of its parent company Chemetall in Germany and Taiwan (Chemetall, undated§). SQM completed its first full year of production in 1997 and has the capacity to produce about 23,000 t/yr (Schmitt, 2001). Both Chilean companies transport concentrated brines from the Salar de Atacama to lithium carbonate plants in Antofagasta.

China.—China is the only country that continues to produce lithium carbonate from spodumene. It uses domestic spodumene from several small mines. Imported Australian spodumene is used as raw material for lithium carbonate production and in ceramics and glass applications. Additional lithium carbonate is imported into China from Chile and the United States. Lithium brines are believed to be the largest lithium resources in China containing 80% of the country's reserves. Production from brine deposits was reported for the first time in 2003, but quantity data were not available. Lithium carbonate plants using brine from the Qinghai Salt Lake and the Xitai Jinaer Salt Lake were under development. These deposits are in very remote areas and have more magnesium than other successful brine deposits; these factors may influence how successfully China fares in the lithium industry (Crossley, 2003a).

Germany.—Chemetall has been a major producer of lithium compounds for many years from its Langelsheim plant lithium operations. The company has lithium operations in Chile, Germany, Taiwan, and the United States.

Outlook

The health of the domestic lithium industry remains closely tied to the performance of the ceramics and glass and the primary aluminum industries in the United States and the U.S. economy in general. Changes in consumption of lithium in these industries determine the performance of the entire lithium industry. With nearly one-third of U.S. aluminum capacity idle since 2001, lithium consumption continued to suffer, and prospects for recovery are low. Increases in USGS estimated lithium consumption indicate improved consumption in other areas, but exactly where is hard to identify.

Prospects for growth are very different from a global perspective. The market for lithium batteries is increasing in value by 12% to 15% per year and the volume of sales is increasing at an even higher rate of 25% to 30%. The differences in these growth rates indicate that as the sales of batteries increase, the price per item is decreasing. Nearly all production of these devises is in Asia, so growth in this application does not affect lithium consumption in the United States.

Lithium-ion and lithium-polymer batteries appear to possess the greatest potential for growth. First introduced in 1993 with minimal sales, the market for these rechargeable batteries was estimated to be $3.5 billion in 2003. Most lithium batteries that are sold are the lithium-ion type, but lithium-polymer batteries are gaining in popularity, representing about 10% of the market, an increase from 5% in 2002. Lithium-polymer batteries are more attractive to many original equipment manufacturers because they can be constructed in unusual shapes to more easily fit into the devices that they power (Crossley, 2003b).

The use of lithium batteries in EVs was believed to offer the potential for future growth in lithium demand for quite some time. Battery-powered EVs have not become as popular as was expected, and they appear to have lost favor with many automakers. Instead, carmakers have shifted focus to developing hybrid electric vehicles (HEVs) that contain small internal combustion engines and battery-powered electric motors. These vehicles are growing in popularity and more models are being developed. Most current HEVs incorporate nickel metal hydride batteries, but improved lithium batteries could replace them in future generations of HEVs, creating increased demand for lithium. Too many unknowns remain, however, to allow for a reliable forecast of the quantity of lithium that will be required for the HEV market. The successful development of fuel cell technology to power automobiles in the future, however, could render battery-powered vehicles obsolete.

Different lithium producers have diverse opinions on what areas offer the most potential for growth. One producer reports surprising growth in construction uses, especially in fast setting concrete. Another company sees its largest growth in the use of organic lithium compounds used as pharmaceutical catalysts. Lithium bromide consumption is reported to be increasing by some producers, but on the decline, especially in the United States, by another. No producers are willing to provide details that closely define their markets, making it impossible to get better estimates of actual markets.

Based on differing reports from a variety of sources, some conclusions can be drawn. Domestic consumption may experience slow growth, but it will take a long time to recover to the level experienced before 2001. Aluminum production and ceramics and glass will remain the largest end uses, although not as dominant as in the past. Continued closures at aluminum smelters could result in permanent shutdowns with no chance of increased lithium consumption at those locations. The closure of the thermal shock resistant cookware factory in West Virginia, once the largest single lithium concentrate consumer in the world, has eliminated a major consumer of those products. Increased popularity of glass cooktops is a growing market for lithium concentrates, but increased consumption will occur in Europe, not the United States. The largest growth area is in batteries, but lithium batteries are mostly produced in Asia, so their growth will not increase domestic lithium consumption. Growth in other lithium end uses will continue, but at modest rates that are even more difficult to quantify than those already discussed.

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TABLE 1
SALIENT LITHIUM STATISTICS [1]

(Metric tons of contained lithium)

	1999	2000	2001	2002	2003
United States:					
Production	W	W	W	W	W
Producers' stock changes	W	W	W	W	W
Exports [2]	1,330	1,310	1,480	1,620	1,520
Imports [2]	2,640	2,880	1,990	1,920	2,200
Consumption:					
Apparent	W	W	W	W	W
Estimated	2,800	2,800	1,400	1,100	1,400
Rest of world, production [3]	15,100	16,900	14,900	16,900 [r]	17,100 [e]

[e]Estimated. [r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Data are rounded to no more than three significant digits.
[2]Compounds. Source: U.S. Census Bureau.
[3]Mineral concentrate and lithium carbonate.

TABLE 2

U.S. EXPORTS OF LITHIUM CHEMICALS, BY COMPOUND AND COUNTRY [1]

Compound and country	2002 Gross weight (metric tons)	2002 Value[2] (thousands)	2003 Gross weight (metric tons)	2003 Value[2] (thousands)
Lithium carbonate:				
Australia	130	$551	26	$90
Canada	331	1,190	124	443
China	100	361	251	903
Germany	1,100	3,120	1,000	3,040
India	53	162	39	134
Japan	1,450	4,800	686	2,850
Korea, Republic of	25	90	182	520
Netherlands	90	333	64	232
Taiwan	20	71	54	123
United Kingdom	175	582	150	531
Other	145	651	85	287
Total	3,620	11,900	2,660	9,160
Lithium carbonate, U.S.P.:[3]				
Australia	45	182	(4)	4
China	39	71	313	659
Germany	138	276	1	33
Other	29	145	6	52
Total	251	677	320	748
Lithium hydroxide:				
Australia	56	237	229	901
Canada	132	515	110	436
Germany	646	2,000	740	2,090
India	521	1,320	713	2,250
Japan	759	3,700	968	4,090
Korea, Republic of	241	846	256	924
Mexico	55	191	104	313
Netherlands	103	406	163	532
New Zealand	22	80	295	689
Singapore	108	395	79	461
Thailand	87	233	180	474
United Kingdom	194	1,170	242	1,090
Other	2,480	9,550	1,750	7,170
Total	5,400	20,600	5,830	21,400

[1]Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Free alongside ship values.

[3]Pharmaceutical-grade lithium carbonate.

[4]Less than 1/2 unit.

Source: U.S. Census Bureau.

TABLE 3

U.S. IMPORTS FOR CONSUMPTION OF LITHIUM CHEMICALS BY COMPOUND AND COUNTRY [1]

Compound and country	2002 Gross weight (metric tons)	2002 Value [2] (thousands)	2003 Gross weight (metric tons)	2003 Value [2] (thousands)
Lithium carbonate:				
Argentina	882	$2,010	3,110	$5,790
Chile	8,660	12,800	8,430	12,000
Japan	138	268	1	9
Other	152	439	44	190
Total	9,830	15,600	11,600	18,000
Lithium hydroxide:				
China	401	1,060	63	189
Japan	14	145	9	78
United Kingdom	6	38	22	165
Other	11	44	17	169
Total	432	1,290	111	601

[1] Data are rounded to no more than three significant digits; may not add to totals shown.

[2] Customs value.

Source: U.S. Census Bureau.

TABLE 4

LITHIUM MINERALS AND BRINE: ESTIMATED WORLD PRODUCTION, BY COUNTRY[1, 2]

(Metric tons)

Country[3]	1999	2000	2001	2002	2003
Argentina:[4]					
Lithium carbonate	1,592 [5]	2,161 [5]	-- [5]	906 [5]	1,000
Lithium chloride	2,794 [5]	5,182 [5]	4,512 [5]	4,729 [5]	4,700
Australia, spodumene	75,824 [5]	81,891 [5]	63,443 [5]	100,000	110,000
Brazil, concentrates	11,122 [5]	10,875 [5]	9,084 [r, 5]	12,046 [r, 5]	12,100
Canada, spodumene[6]	22,500	22,500	22,500	22,500	22,500
Chile, carbonate from subsurface brine	30,231 [5]	35,869 [5]	31,320 [5]	35,242 [r, 5]	35,000
China, carbonate	12,500	13,000	13,000	13,000	13,500
Portugal, lepidolite	14,862 [5]	9,352 [5]	10,000	9,500	9,500
Russia, minerals not specified[7, 8, 9]	2,000	2,000	2,000	2,000	2,000
United States, subsurface brine	W	W	W	W	W
Zimbabwe, amblygonite, eucryptite, lepidolite, petalite, and spodumene	36,671 [5]	37,914 [5]	36,103 [5]	29,838 [r, 5]	24,000

[r]Revised. W Withheld to avoid disclosing company proprietary data. -- Zero.

[1]Table includes data available through March 28, 2004.

[2]Estimated data are rounded to no more than three significant digits.

[3]In addition to the countries listed, other nations may produce small quantities of lithium minerals. Output is not reported; no valid basis is available for estimating production levels.

[4]New information was available from Argentine sources, prompting major revisions in how lithium production was reported.

[5]Reported figure.

[6]Based on all Canada's spodumene concentrates (Tantalum Mining Corp. of Canada Ltd.'s Tanco property).

[7]These estimates denote only an approximate order of magnitude; no basis for more exact estimates is available.

[8] Lithium contained in concentrates and brine.

[9]Other countries from the Commonwealth of Independent States, including Uzbekistan, could have produced or could be producing lithium, but information is not available for estimating production levels.